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Science and Agricultural Development. †

BY

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The close connection of science with agricultural development is so obvious that it seems hardly necessary to emphasize it. What more or less accurate knowledge we have of the formation of soil and of its adaptation to the needs of plants has been obtained by workers in the fields of geology, physics, chemistry and biology, and to fill the huge gaps that still exist in that knowledge we shall require the services of workers in these fields for an indefinite number of years to come. The numerous and intricately combined factors which go to make up what is known as soil fertility are still but imperfectly understood and when we come to a consideration of the fertility of particular types of soil our knowledge is still more imperfect.

What applies to the soil applies with even greater force to the living beings, plants and animals which depend directly or indirectly upon the soils for their food and thus for their development. It must be evident, therefore, to all that the scope for scientific investigation in the field of agriculture is practically unlimited.

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The need for such investigation is in few countries of the world more insistent than it is in India and this for two reasons. In the first place the number of workers in the field are, in comparison with the variety and number of the problems, the size of the population, and the extent of the country, almost ludicrously insufficient. In the second place we have to face the fact that no matter what may be done in the way of the development of industries in this country, the pressure of population on the land already heavy, is likely to increase. If therefore we are to raise the standard of living among our agricultural population, we shall have to produce very much more per acre than we are now doing. Much can no doubt be done in this direction by the dissemination of knowledge as regards improved stock, improved seed and improved methods of cultivation and manures which are already available and that is a very important function of any Agricultural Department. However there is a real danger that our efforts in this regard may outrun our real knowledge and examples are by no means lacking in this country of more or less disastrous results following attempts to introduce improvements the value of which has not been established by sound and accurate investigation. The temptations in this direction are very many and very great. I think I may safely say that there is hardly a worker in India who has not taken considerable risks in the recommendation of agricultural improvements, real or imaginary, before he had thoroughly satisfied himself of their value to agriculturists. The insistent demand for practical results from all sides and the knowledge that the provision of funds for the continuance of work already begun, not to speak of the expansion of work into new fields, will depend upon what appear to be practical results, has virtually forced the most conscientious of us to take such risks.

From what I have said it must be obvious that if we are to meet the needs of the future as regards agricultural development, work in the sciences as related to agriculture will have to be greatly widened and deepened, and a very much larger number of trained men will have to be engaged in this work than is now the case.

Even as regards the investigation work at present being done, it is to be feared that much too narrow views are frequently held. Let us take, as an example, the production by plant selection of higher yielding strains of the crops already being grown. This is, as you no

doubt all know, the type of scientific work that has upto the present furnished us in India with the most striking results of the application of science to agriculture. The very popularity of this work and the rapidity with which the cultivation of new and higher yielding varieties of important crops has extended, introduce very definite dangers for the future. It is, I believe, generally admitted that we have in India in general (there are of course many exceptions) an agriculture stabilized at a low pitch of crop production. Under such conditions the amount of crop produced by any variety or mixture commonly grown will depend almost entirely upon the plant foods added each year to the soil. If we now introduce a more efficient plant which is able to utilize more fully the plant foods contained in the soil, we shall almost of necessity upset this equilibrium. It seems to be clear that we shall gradually, it may be unperceptibly, lower the fertility of the soil unless we, at the same time, add to it more plant foods in the way of manures than have heretofore been added. I was, I believe, the first in India to emphasize this point in my presidential address before the agricultural section of the Indian Science Congress about twelve years ago. It has since then been emphasized by others. I mention it here simply to indicate to you the necessity of balanced scientific effort in all directions if we are not to run the risk of permanent injury for the sake of temporary advantage.

From my emphasis of the importance of scientific investigation on a large scale for the development of Indian agriculture some of you may suspect that I am one of those who are blind to the value of pure science, a phase of scientific study the supreme importance of which has no doubt been impressed upon you by your various professors. May I assure you at once that no one places a higher value upon pure science or the acquisition of fundamental scientific knowledge than I do ? My whole early training so impressed that upon me that I could not shake myself free from it if I would. It is idle for me to tell you now what dreams I had of tackling problems in pure science when I came to India twenty years ago. Suffice it to say that all those dreams have long since vanished in the struggles with the immediate problems which have continually faced and at times almost overwhelmed me.

I presume some of you have dreams similar to the ones that possessed me. What are the chances of their fulfilment ? Few of

you will, I fear, be in that most fortunate position of having to worry not at all about making a living and even these few will hardly be able to persuade their fathers or fathers-in-law that the career of an investigator who gets not even a salary to help support him is a suitable one for their sons. We might perhaps dream that in some distant future science would become so revered in this country that what I might call Sanyasis of Science could go from door to door with begging bowls and be sure of obtaining enough to sustain them in their scientific labours. I fear, however, for the present most of you will have to map out your career not according to taste but according to necessity. Lucky the men who in doing so find some opportunity of utilizing their natural abilities and their University training to some degree satisfactorily. Of these, I fear, only the few who are appointed to University positions will have much opportunity for carrying out investigations in pure science and even they are likely to find their paths beset with difficulties.

If we come to the question of applied science opportunities are undoubtedly greater and are likely to become still more numerous in the future. Of such opportunities probably none are fraught with greater importance to the economic life of this country than those connected with science as applied to agriculture. In that weighty volume recently published which seems destined to become a scientific Bible or shall I say Gita to the agricultural workers of this country, special stress is laid upon the importance of enlisting the services of the Universities in the work of agricultural uplift. I agree with the view there expressed and it may be wondered why under these circumstances my support of the scheme to establish an agricultural faculty in the University has in the past been lacking. The reason is a purely economic one. I am given to understand that Mysore is able to absorb into employment, where University training can be economically utilized, only about one-half of our graduates. These figures may be incorrect but in any case a large number of our graduates go to swell the ranks of the unemployed. These may remain for several years a severe burden on their parents later to drift into more or less subordinate clerical posts where their training can obviously be but imperfectly utilized. My own view is that we are at present spending a disproportionate amount of our educational budget on our University. It would surely be unwise to establish another and what

must be a fairly expensive faculty in the University without at first collecting some evidence to show that the graduates from such a faculty would have some better fate than to swell the ranks of the educated unemployed. Some years ago I estimated that the demand for graduates from such a faculty to fill special posts where they would not seriously compete with graduates from other faculties would absorb just about half the number of graduates that would be turned out. What is to happen to the other half and have we any definite evidence that they would be prepared to go in to the land and if so, whether their training would make them more useful and successful farmers than they would have been, had they undergone training in a vernacular agricultural school or an agricultural school such as Hebbal or as a matter of fact in a high school or in an arts course of the University ? One of our most successful agriculturists is an Arts Graduate of the University of Madras. Many others have had but very meagre general education and no special agricultural training whatever.

In my opinion we must have some definite evidence that the agricultural training that we are able to give in a faculty of agriculture confers definite and special benefits upon those who take it before we should be justified in launching out on what must after all be fairly large expenditure. We should be able to collect some evidence either for or against this assumption within two or three years after the proposed scheme of agricultural colonization comes into being. The essential feature in that scheme is the placing of men trained in Agriculture either from a college or from our Hebbal School on suitable areas of Government land and with sufficient initial assistance to enable them to show whether or not they can make a decent living and whether their training has really helped them to that end. If this scheme is a success, as I hope it will be, we can see at least one method of reducing the numbers of our educated unemployed.

The question of the educated unemployed is a serious one and has in my opinion not received the attention it deserves. Much is heard of unemployment in England. I should like to ask you, which is more likely to have serious and permanent consequences to a country, unemployment among the labouring classes, who after all have cost the country but little to educate and who individually can be expected to contribute but little to a country's prosperity, or unemployment

among the educated classes from whom must be developed the intelligent leaders in town and village who are now so sadly lacking in Mysore ? There can, I think, be but one answer to that question.

Gentlemen, you may consider this a rather unsuitable address for an occasion such as this but I should like to think of you as those who are anxious to put their manhood and their interest in their country above their special scientific interests and would therefore already have begun to think of this country's future in terms not entirely personal. If India in general and Mysore in particular are to progress, that progress must be very largely based upon a development of our main industry, agriculture, and that will call for the best in brain and heart both inside and outside Government service which this country can produce.

Improvement of Bee-Keeping.*

BY

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Assistant Entomologist.

Bee-keeping is undoubtedly a fascinating occupation for one and all. For agriculturists in general and growers of fruit in particular, it is of especial benefit. Bees have, in nature, a profusion of honey-yielding plants in the forests. Hundreds of colonies of rock-bees, as well as those of the partially domesticated Indian bee, have long been gathering tons of honey and have provided many a man in the *malnad* with a sure means of livelihood. In cultivated areas also bees are at work but the beneficial nature of their activities is a fact that is seldom given the serious attention it deserves. The coffee growers as well as all other orchardists here, must come to recognize the usefulness of the honey bees to a much greater extent than they do at present and they should provide increased facilities and afford proper encouragement to the bees in their splendid work for the good of the cultivator.

Needless to say, bee-keeping has long been a subsidiary industry in most parts of the *malnad*. But nothing has at any time been done to pursue the industry on improved lines. The existing condition of

*Note read at the Eleventh Annual Meeting in November 1928.

the industry is very far from satisfactory. Many ryots there keep bees in pots ranging in number from half a dozen to 30 or so. It is not to be imagined that they pay even half the amount of attention to their bees that they bestow on their cattle, the latter being of course in not very enviable position themselves.

Bee-keepers in the *malnad*, first leave a number of pots, each with a few small holes on a side, in suitable places in forests, about the month of January or even earlier. It is customary to use only such pots as had been previously occupied by colonies of bees, or if they have to supplement the old pots with fresh ones, they smear the inside of the latter with wax and sometimes some old honey, the idea being to attract swarms to the pots. It is likely that the majority of the pots are soon after occupied by swarms issuing from different localities in forests and migrating in different directions. Just after the commencement of summer and when general blossoming begins, the ryots remove to their own habitations the now tenanted pots in which two or three small combs will have already been built and egg laying by the queen and rearing of young ones started. These pots are placed by them in all manner of situations, under trees, in hollows and branches of tall trees,also scattered among coffee shrubs, arranged close together underneath the gables or sometimes on platforms even in the interior of their huts. Pots with bees, inverted on stone slabs, in coffee estates, are not uncommon. When once the pots are thus disposed of, the ryots seem almost to forget their existence till after crops of honey are ready to be harvested from them a few months later. During this interval, the bees shift for themselves, struggling hard to fight their numerous natural enemies and adverse weather conditions. Ants, wasps, blood-sucking bugs and web-building caterpillars are a few of the enemies. The pots do not admit of frequent examinations of colonies inside and of supplying any extra conveniences needed by them. Such of those colonies that are strong enough in numbers and are working away vigorously, withstand successfully the onslaught of their enemies and continue to thrive. Others being gradually victimised by the enemies, later desert the pots. The ravages of the enemies are especially in evidence during the monsoon months. Hornet wasps, carnivorous ants and wax moths become extra active then and contribute vastly to the critical condition in which many colonies are left in that season. What with

the havoc caused by the enemies and the fall in the rate of multiplication in the colony together with little or no honey gathered at this time, the majority of the colonies suffer seriously.

Usually two crops of honey are taken in the year. At times a third crop is taken too but that depends on the number of colonies owned by any individual in a particular locality and favourable seasonal conditions prevailing there. The first harvest is gathered in the months of March and April and sometimes May and the second in September and October. It must not be imagined, however, that the two crops are obtained from one and the same set of colonies, because the indigenous method of harvesting does not admit of such a thing. The ryots do not wait sufficiently long for the honey in the combs to ripen but they simply grab at whatever they can lay hands on in the season. And the manner in which they do it is a harrowing tale. They turn the pots over and smoke the colonies and sometimes burn them out. The bees either escape, if they can, or get scorched and die. The combs are cut out and packed in any thin, dirty cloth, and then the whole thing is twisted and squeezed by the hand. In this process the honey which is first of all mostly unripe gets mixed with the juices of young ones of different stages contained in the cells of the combs while the combs themselves are reduced into shapeless lumps of wax. This adulterated honey is finally strained through another piece of linen and stored in all sorts of receptacles. Straining does not leave the honey any better, for juices of young ones get inseparably mixed with it. And the receptacles not being provided with tight stoppers, quantities of moisture are constantly absorbed and fermentation is thus hastened. It is this type of honey that is to be obtained all over the *malnad* and what is to be had in the bazaar is often worse, being further diluted with ordinary sugar-syrup.

It is clear that a single crop of honey from a colony means the desertion or destruction of that colony, death of hundreds of young ones and annihilation of many beautiful wax combs built with enormous labour on the part of the bees. And after all, the quantity of adulterated honey obtained from a colony in a pot, rarely exceeds 4–6 pounds. The consumers of this honey, it is interesting to note, are to a certain extent aware of adulteration but they invariably ascribe it to dilution with sugar-syrup and it is hardly likely that even one in a hundred, suspects the mixture of the juices of young ones with the

honey. If at all this fact becomes common knowledge, sure enough, sentimental objections gain the upper hand among a large number of people and even the meagre use to which honey is now being put will be stopped and the greater part of the honey produced in the *malnad* will have practically no market. This ought to be looked upon by the bee-keepers in the *malnad* as a contingency rather too disquieting to be ignored.

The glaring defects in bee-keeping in the *malnad*, as seen from the account given above, can all be overcome by the introduction of improved methods. First of all, the present practice of keeping bees in pots must be discontinued. Pots can be used only for securing colonies from forests. Even for this purpose, pots need not be the only means. They can be replaced by what are called " loghives ", which are portions of date palm stems hollowed out and fitted with two circular planks screwed down to the two open ends. These afford better facilities for bees to start a colony. Whatever is used initially, either pot or log, when once the attracted colonies are brought home, the bees and their nests must be transferred to improved hives made of teakwood. These hives are so made as to afford excellent facilities for the work of the bees. Each hive consists of a bottom board into which is adjusted the bottom chamber with a number of parallel frames inside. In this chamber the queen lays eggs and the young ones are reared. Below the chamber an opening is made for the bees to get in or to get out of the hive. Above this chamber are adjusted two other chambers of smaller size, also with frames, where all surplus honey is stored. Topmost of all is the hive cover. The component parts of the hive are easily taken out when necessary. The idea of having different chambers for rearing of young ones and for storing honey, is to obviate the chances of honey getting mixed with young ones as happens in the pot, for the queen confines herself to the lowest chamber and eggs are laid only there. The surplus honey over and above the quantity used by the bees themselves for purposes of feeding, being stored in the two upper chambers, can be taken in its purest state.

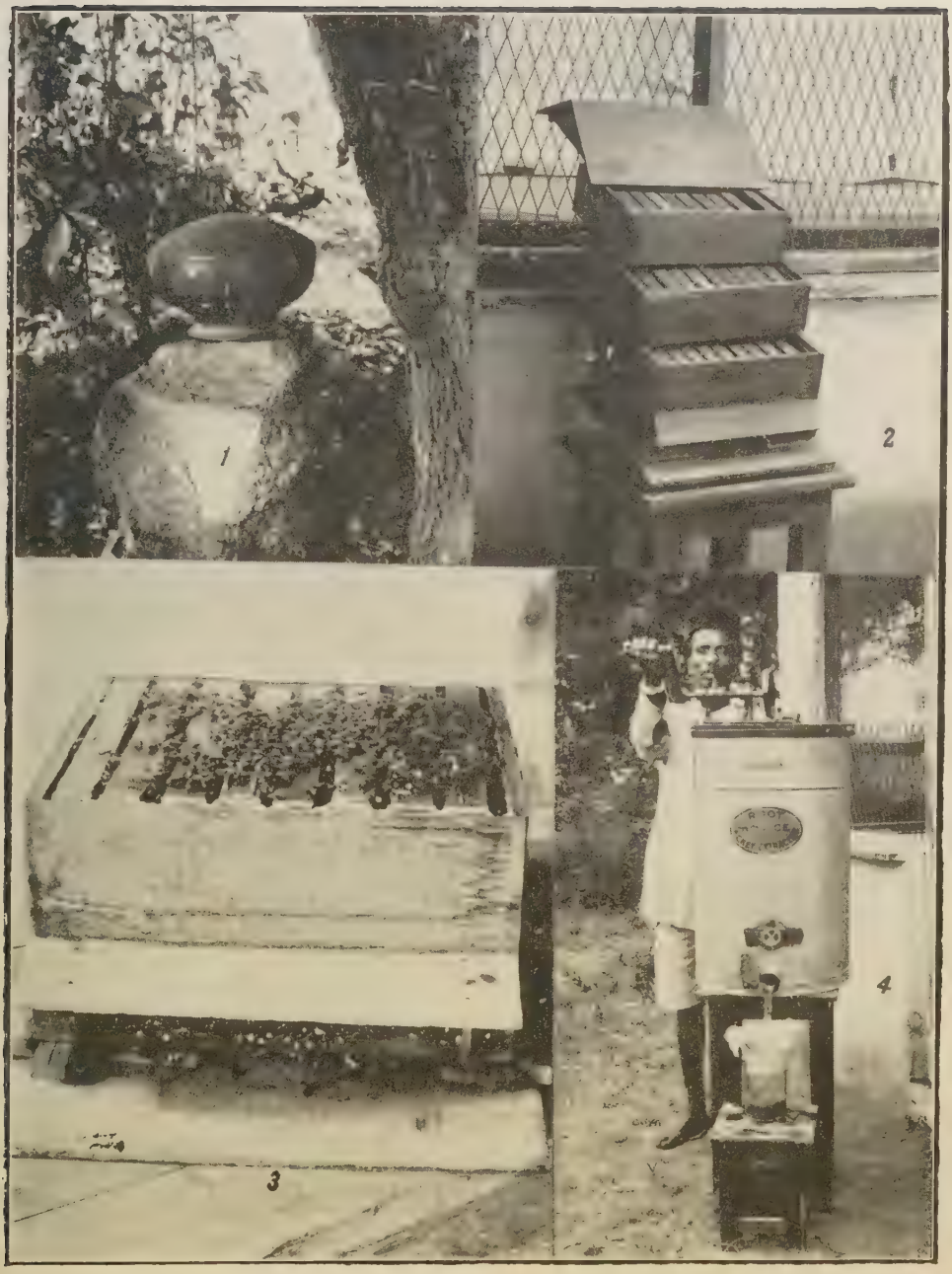
As for transferring bees from the pot to the improved hive, it is done more usually after dusk when all the bees are in and are fairly quiet. The pot containing the initial set of combs with the bees is turned over, the bees made to cluster on a side of the interior by the

gentle application of a little smoke, the combs cut out one by one at the places of their attachment to the roof of the pots and tied to the larger-sized wooden frames. These latter with the combs intact are arranged in the bottom chamber parallelly so that all or most of the eggs and young ones are confined there. Full combs or pieces of them containing honey are fixed to the smaller frames and arranged in the upper chambers. Then the clustering bees in the pot are dumped on to the surface of the frames and the hive closed by the cover.

Frequent examination of the several combs, maintenance of sanitary conditions inside the hives, prevention and remedying of attacks from natural enemies, easy provision at intervals of enough space for storing surplus honey and the supply of certain extra conveniences for more vigorous work of the colony, are all special advantages of the improved hives and are scarcely to be had in the pot hive. By far the greatest advantage is the taking of honey in its purest condition and in larger quantities than has so far been possible from colonies in pots. The increase in quantity ranges from four to eight times and too much stress cannot be laid on the entirely good quality of the honey.

The surplus honey, we know, is stored in places exclusively meant for the purpose in the improved hive and it is extracted by means of a specially devised extractor helping to throw out the honey in the cells by centrifugal force. This prevents adulteration with juices of young ones, bits of wax and filth from human hands completely. Not a single bee, either young or adult, is killed, and combs are not in the least damaged. The result of all this is that the same colony of bees, with the same set of combs once produced by them can be used for several years. The work of producing wax and building fresh combs tax the bees heavily and if this work is taken off their shoulders the energy conserved thereby is used for the more profitable purpose of gathering honey and as a matter of course the surplus will increase many times over; for it has definitely been established that the production of 1 lb. of wax by the bees entails the consumption of anywhere from 10-20 lbs. of honey by them.

The improved hive, being made of teakwood, is doubtless far superior. Apart from its several advantages enumerated already it has to its credit also, its extreme durability and least liability to



1. Pot used to keep bees in the *Malnad*.
2. The several sections of the improved hive.
3. The upper surface of the brood chamber of the improved hive, showing bees at work.
4. Extraction of honey by means of the Extractor.

breakage. An average bee-keeper can make use of the same wooden hive for the whole of his life-time. This must amply justify the initial outlay.

The two most important ways in which improvement in bee-keeping can easily and immediately be effected, are, therefore, by keeping and rearing bees in improved hives and harvesting honey by the use of the extractor.

But it has to be borne in mind that the transition period between the first introduction of improved methods and the time when the Indian bee can confidently be said to have become well accustomed to the same, is bound to be one of deep concern to every one interested in the improvement of bee-keeping. Early disappointments there will be and will certainly loom large and serious. The Entomological Section of the Department has had to face disappointments and difficulties in the course of its work. The chief difficulty, at the very commencement, occurred in the shape of frequent desertions of colonies from improved hives. But the stage has now been reached when the original frequency of desertion can be said to have been largely minimized through repeated trials and close investigation into the leading causes. It is to be admitted, however, that, on the whole, colonies in the *maidan* have hitherto run fairly more permanently than those in the *malnad*. As already pointed out, the monsoon season forms a critical period in the life of a colony ; far greater care is necessary in the *malnad*, if colonies have to tide over the critical period successfully. But all the same, there cannot be any doubt as to the possibility, by virtue of prompt and judicious attention and handling, of inducing at least the greater majority of the colonies in any locality in the *malnad*, to continue in good working order all the year round.

The quantity of honey hitherto taken from individual colonies reared in improved hives has ranged between 15—25 lbs. per annum. While this is by no means inconsiderable here, the chances of obtaining richer harvests are certainly bright. The quality being far superior to the crude indigenous product, the market value is enhanced three to four times.

If bee-keeping has to be established on sound and commercially profitable bases, some special items of investigation have to be taken

up. Two of them are of the utmost importance. One is queen-rearing. This is a piece of work which has not been tried in India yet. Rapid increase of colonies in any apiary is impossible if extra queens are not reared. Under the present conditions, every time an additional colony is required it has got to be attracted in gardens or forests during the swarming seasons of the year. By having spare queens ready, big colonies might easily be split and the queenless halves supplied with queens. Another advantage of having extra queens on hand is that weak colonies can be made strong so as to facilitate rapid multiplication and growth in bulk of the colony as a whole and a consequent increase in gathering power. This is done by removing the old or otherwise incapacitated queens from weak colonies and replacing them by young and vigorous ones. Among the several colonies in the departmental apiary at Bangalore there have been some three which have remained in the same weak condition ever since they were started more than a year ago whereas others brought in exactly at the same time and treated in precisely the same manner, have grown quite satisfactorily. While the latter have already yielded from 15 to 20 lbs. of honey the former have yielded nothing. All other conditions remaining identical, the only explanation for this must be that the queens of the colonies in question are aged and have lost their capacity for rapid reproduction. It is well known that after two to three years of vigorous egg laying by any queen, her vitality diminishes to a very appreciable extent. In fact, in many apiaries run on up-to-date lines in the West, queens of colonies are replaced almost every year.

The second item of investigation relates to the introduction of foreign bees such as the Italians. The latter have been famous for their perfectly domesticated nature and their immense gathering power. Risks there are, of course, attendant on such an introduction. While fortunately diseases of honey bees are yet unknown in India, they might, by chance, be imported along with the foreign bees which are subject to several of them in their native countries. But considering the advance that scientific apiculture has reached in the West, it must be possible to import successfully only such colonies as are entirely free from any disease. Steps might then be taken to bring about a cross between the foreign and local bees with a view to derive an improved strain of bees over the indigenous ones. All

this means, of course, work spread over several years and is therefore, not of immediate possibility.

It remains to be said finally that the Section has, in spite of several handicaps, distributed in the course of about 18 months, more than a dozen improved hives with colonies of bees, among coffee planters and others in the *malnad*, besides having nearly 20 colonies working in the two apiaries, one at Bangalore and another at Kottigehar. This is but fairly satisfactory so far under the existing circumstances, and the Section will try to help, in every possible way, intending keepers of bees on improved lines in different localities.

The Improvement of Cattle Breeding Industry in Mysore*.

BY

C. Narasinga Raju, L.Ag., *Live-Stock Officer.*

Of all the problems confronting the Mysore agriculturist at the present day the problem of improving the cattle breeding industry and saving the famous Mysore breeds from degeneracy, demands his earliest attention and genuine efforts to solve it. We may say that there is progressive deterioration of soil consequent on its exhaustion by perpetual cultivation, ineffective tillage and insufficient manure. "Tillage is poor man's manure." To promote efficient tillage with modern implements, we should build up an efficient labour power. The chief animal power which is within the reach of an ordinary man and which can supply the required motive power and also the manure, is the bullock.

Mysore has enjoyed from a very early period a just renown for superior breeds of cattle for draught purposes. The cattle trade brings in nearly a crore of rupees to the State. But no one can ignore the fact that conditions obtaining to-day show that there is deterioration of the breeds of cattle. Instead of pure and valuable breeds, large herds of poor mongrel cattle are to be met with everywhere. Many of them are worthless, being too weedy even to put into the lightest implement, and they are allowed to exist and eat the ration of the more profitable ones. The value of pure breeds is very often lost sight off.

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* Note prepared for the Eleventh Annual Meeting held in November, 1928.

Mysore is a land of petty breeders. Systematic cattle breeding on a large scale is absent. This is chiefly due to want of capital and the risk of rearing animals which may afterwards fall a victim to contagious diseases which visit our State every year and levy a heavy toll. The present deplorable state of cattle breeding is mostly attributable to the existing pernicious system of communal grazing of cattle on Gomal lands. The defects of this system and the remedy suggested are given in an article on "Evil Effects of Communal Grazing" published in the Departmental Calendar for 1926. The most important causes of deterioration are indiscriminate breeding, insufficient feeding and care, and above all mortality from contagious disease which damps the spirit of even an enthusiastic breeder of cattle.

Indiscriminate Breeding.—The only method of putting this down is by a rigorous campaign of castration of all scrub bulls and the introduction of a sufficient number of good breeding bulls. How far has the State accomplished these ? A large number of scrub bulls are castrated every year due very largely to the efforts of the Civil Veterinary Department. For lack of liberal policy very few bulls have been distributed although there is a great demand for them. Various schemes have been introduced for the improvement of village cattle but very little has been achieved for want of sufficient money and material. Among the schemes introduced may be mentioned :—

1. *Stationing Bulls in Veterinary Hospitals maintained by Local Bodies.*—The majority of the cows covered by these bulls belong either to official or merchant class of people or professional cow-keepers who are not so much interested generally in raising good animals as in increasing the yield of milk ; consequently these bulls are of very little use to cattle breeders of the village.

2. *Itinerant Bulls.*—Some of these were kept on circuit in villages round about. Even these have failed to bring about the desired effect for reasons that the number of bulls were very few and the scheme was tried when there was scarcity of fodder with the result that they were not properly fed in the villages and had to be taken back. Further, the period of halt in a village was too short to cover many cows.

3. *Granting Subventions* to owners of breeding bulls who kept them as per conditions laid down by the Department. These grants were not availed of by many probably for want of sufficient publicity to the scheme and lack of funds.

Very little progress will be made in the improvement of cattle until and unless a good number of breeding bulls are made available at a reasonable price. Difficulty is felt in purchasing bulls from breeders in villages where better class of cattle are raised, as they keep generally only the number required for their breeding purposes. The Amrut Mahal herds which we all naturally look to for a sufficient supply of breeding bulls, are practically of no use. Bulls available from these herds are of so unruly and dangerous a disposition that it is very difficult for the ryots to domesticate them, unless it be from very young age.

Having one of the finest strains of cattle for draught purposes it is a pity that for want of a change in the policy of the Amrut Mahal Department the Mysore breeders derive very little benefit from it. The Amrut Mahal Department ought to be able to meet the demand for breeding bulls to a very appreciable extent, by careful and systematic breeding and management of the existing herds. Production of a few good breeding bulls here and there cannot improve our situation. There should be 'mass' production of good breeding bulls for distribution. It is only then may we be able to make any substantial improvement. We may follow the example of the Punjab in this direction, where hundreds of bulls are raised every year on Government farms and sold to breeders. I think Mysore has much better natural advantages than the Punjab for cattle breeding, but unfortunately we have lagged behind for lack of a liberal policy and effort.

Insufficient Feeding and Care.—No amount of good breeding, however, will overcome the ill-effects of bad rearing and insufficient feeding which is so often practised. Unfortunately we are only too well aware of the existence in almost every village of large numbers of ill-bred and half-starved cattle which share the food and water of more useful animals. It pays better to maintain a few good animals than to keep a number of worthless ones. The deterioration of cattle can very effectively be solved by a liberal system of feeding, especially of the young growing animals. Restriction of the number of cattle

kept, better management of *Gomal* lands and pastures, cultivation of fodder under irrigation wherever possible and conservation of fodder will go a great way to solve the problem of insufficient feeding.

Contagious Diseases.—Every year we sustain a heavy loss on account of cattle mortality by contagious diseases. Even a most progressive cattle breeding policy cannot hope to succeed, which does not include in it the prevention and control of contagious diseases by timely and adequate veterinary aid and suitable and judicious legislation.

The best way to solve the problem is by better feeding, better breeding and better veterinary aid. These could be done only with the help of a more liberal and continued policy on the part of Government and local bodies and persistent efforts of cattle rearers.

Serum Simultaneous Inoculation

OR

Active Immunization.

BY

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Rinderpest is an acute, febrile, contagious disease of ruminants, particularly cattle, and like other contagious diseases, it is caused by a living parasite which is of such a small size that it cannot be readily detected even with the highest powers of the microscope. The mortality caused by this disease is very high in India, and as a result, the cattle-owners sustain heavy losses. As there is no known successful curative treatment when once an animal is attacked by the disease, we have solely to depend upon prophylactic measures, and the only method that was universally in vogue was the "serum alone" method of inoculation in the scenes of outbreaks, which would confer an immunity of a very short period of 9 days ; but with the advance in the knowledge about the disease another better and more effective method of protection was evolved, *i.e.*, "Serum simultaneous inoculation" or "Active immunization".

This method of immunization is based on the main principle that cattle recovered from Rinderpest are subsequently immune to the disease apparently for the rest of their lives. They develop this

immunity in virtue of the well-known fact that their tissues respond by elaborating certain antibodies, which can readily be detected in their blood or blood serum a short time after their recovery. The serum of such recovered animals containing the so-called antibodies can be used to protect cattle, but the immunity thereby conferred lasts only for a short time (9 days). In the method of active immunization the animal is caused to manufacture its own antibodies in exactly the same manner as if it were made to pass through the natural attack of the disease and the immunity developed subsequently is a very long and solid one, although in rare instances it is not life long. The only difference between the natural attack and the process of active immunization is that in the former, the attack very often ends fatally, in the latter the severity of the attack is artificially controlled, and when the control is at its best the animal does not show any outward signs of bodily disturbance.

The operation is carried out by inoculating the animal subcutaneously with a certain dose of serum, estimated to be more than adequate to protect it against the development of an attack of clinical Rinderpest, and simultaneously with a small dose of virulent blood withdrawn from an animal at the height of the febrile period of an attack of Rinderpest. If the animal were inoculated with virulent blood alone it would contract a severe, probably fatal, form of the disease. The protection conferred upon the animal by the serum, however, keeps the attack in check to such an extent that no outward sign of disease is seen ; usually there is a mild attack of fever, but very often there is no distinct rise of temperature after the lapse of a few days following upon the inoculation. The serum to be used for active immunization should be of high potency and the fact should have been borne out by careful animal test and standardization. As various breeds of cattle exhibit marked difference in susceptibility towards Rinderpest the dosage of serum to be administered for adequate protection should be carefully calculated.

Virulent Blood.—Blood taken from an animal during the height of Rinderpest reaction is virulent in extremely small quantities and half to one cubic centimetre is usually administered subcutaneously into each animal simultaneously with the serum. The blood retains its virulence for about 10 days if kept sterile in paraffin-coated sealed bottles. It is well to inoculate one or two calves of small value with

the blood without serum to ascertain its virulence. In order to make sure that all the animals become infected while under the influence of the serum, they are again inoculated with blood at the rate of 5 c. c. and this should be performed in from 5 to 8 days after the first inoculation. The second inoculation is not necessary if the animals show a reaction to the first inoculation.

As Rinderpest is a serious contagious disease great care should be taken to exclude all possibilities of spreading the infection from inoculated to other animals in the places that are not submitted to the process. Animals that are very weak or debilitated from any cause should not be inoculated. Cows in pregnancy should be given "block-out" doses of serum to obviate any reaction, as the slightest reaction will bring on abortion, especially in cows from five to eight months in calf. Disturbances that are likely to occur in the inoculated animals will be very slight if the serum is of sufficient potency and the blood used is infective, but we may expect a distinct rise of temperature to occur in the form of a gradually ascending and descending curve between the 4th and the 9th day. Any severe disturbance such as mouth lesions, diarrhœa, etc., would show that the serum injected was either insufficient or not of the proper potency.

Piroplasmosis or red water, caused by the invasion of red blood cells with numerous animal parasites (Piroplasms), is one of the common complications likely to occur in the course of immunization, particularly of imported cattle, and the usual symptom is the sharp rise of temperature usually between the sixth and the twelfth day with or without red urine. This complication can be treated by the injection of 100 c.c.s of a one per cent freshly prepared solution of trypanblue, preferably by the intravenous route. If this does not produce a drop in the temperature in about 6 hours, or the constitutional symptoms become serious, the injection should be repeated.

Coccidiosis, caused by minute egg-shaped animal parasites (Coccidia) in the digestive tract, is another common complication, evinced by symptoms of dysentery and diarrhœa during convalescence after a reaction to Rinderpest. This can be avoided to a great extent by administering a "block-out" dose of serum to prevent all clinical disturbances due to Rinderpest during immunization and thereby obviating the selected depression of the gut wall.

On the whole the loss due to the above complication is negligibly small when it is calculated over a large number of cattle inoculated properly by the simultaneous method.

In this connection it may be interesting to know that the Mysore Civil Veterinary Department resorted to simultaneous method of inoculation on a large scale from September 1925, and have protected by this method 1,37,002 head of cattle against Rinderpest up to the end of July 1928. "Serum alone" method of inoculation is completely suspended from July 1927 and "Serum simultaneous inoculation" is the exclusive measure of protection now universally adopted in the State. The mortality during immunization works out to less than 1% on an average.

Consequent on the opening of the Mysore Serum Institute at Bangalore in 1926 for the manufacture of indigenous serum and virus, the cost of active immunization works up to eight to twelve annas per head of cattle according to size and breed.

NOTES AND COMMENTS.

Economic Use of Water for Irrigation.

We appreciate the kind thought which prompted the Mysore Engineers' Association in keeping open the Essay Competition on the subject of the "Economic Use of Water for Irrigation" to members of the Union. The rules for the award of prizes are published below.

We propose to say nothing more on the subject than that the Engineers' Association could not have chosen a more fitting subject for a competition which is kept open both to the Engineers and Agriculturists. On few other subjects would the interests of both be identical; on none other do both require to understand and appreciate each other's points of view better. (N.V.S.)

RULES FOR THE AWARD OF PRIZES AVAILABLE FOR THE YEAR 1929.

Two prizes of the value of Rs. 50 each in the form of a Gold Medal, called "The Mysore Engineers' Association Medal" will be awarded according to the following rules for papers to be presented on:—

(1) Economic Use of Water for Irrigation, and

(2) Railway Development *versus* Motor Transport.

2. Competition for both medals will be open to all Engineers in Mysore, in addition to the first being open to the members of the Agricultural Department of the Government of Mysore as well as Members of the Agricultural Union, Bangalore.

3. Papers entered for competition shall be judged by a Committee called "The Association Prize Committee," to be appointed by the Executive Committee.

4. Papers to be eligible for competition shall relate to the specified subject and must be the *bona-fide* production of the contributors and must not have been previously made public nor contributed to any other professional body or publication in whole or in part.

5. In the event of the Committee not considering a paper in any one year of sufficient merit, no award shall be made.

6. The right of publishing any one or all papers sent on competition shall vest with the Committee and contributors will not be entitled to claim their papers back whether accepted or not.

7. Papers intended for the said prizes shall be sent in sealed covers with the names and addresses of the authors duly written, to the address of the Honorary Secretary, Mysore Engineers' Association, Bangalore, so as to reach him by the 30th of April 1929.

8. The result of the competition shall be duly notified to the authors concerned and published in the *Mysore Engineers' Association Bulletin.*

SELECTIONS.

Soil Erosion: A National Menace.

Not less than 126,000,000,000 pounds of plant food material is removed from the fields and pastures of the United States every year. Most of this loss is from cultivated and abandoned fields and over-grazed pastures and ranges. The value of the plant food elements (considering only phosphorus, potash and nitrogen) in this waste, as estimated on the basis of the chemical analyses of 389 samples of surface soils collected throughout the United States, and the recent selling prices of the cheapest forms of fertilizer materials containing these plant nutrients, exceeds 2,000,000,000 dollars annually. Of this amount there is evidence to indicate that at least 200,000,000 dollars can be charged up as a tangible yearly loss to the farmers of the nation. These calculations do not take into account the losses of lime, magnesia and sulphur.—H. H. Bennett, Bureau of Chemistry and Soils, U. S. A. Department of Agriculture.—*Agricultural Gazette of N. S. W.*, Vol. XXXIX, Part 9.

Longevity of Crop Seeds.

By K. M. Sonavne,

Seed-Testing Section, College of Agriculture, Poona.

In the course of our seed-testing work, we have often found seed samples, apparently quite sound, to be defective in germination. Age was usually suggested as the reason but we had no precise data regarding this point. There is a common belief that crop seeds more than a year old do not germinate satisfactorily and that an addition of another year renders them completely unfit for use. With a view to ascertain the facts, a longevity experiment was conducted in the seed-testing laboratory of the Poona College of Agriculture. The experiment is now in its sixth year and judging from the results obtained so far, it would appear that it will still be several years before the seeds entirely lose their viability. Seeds from crops grown on the College Farm were used for the tests. Each sample after drying and cleaning was divided into sixteen sub-samples stored separately in glass bottles with a naphthaline ball in each bottle. The bottles were then sealed. Each bottle contained about 4 oz.

of seed. One bottleful was a year's sample and was tested once every three months, the bottle being resealed after each test.

The germination tests were carried out indoor in the laboratory by simple methods. Excepting *bajri* (*Pennisetum typhoideum*) and *til* (*Sesamum indicum*), all the seeds were tested in flower-pots which were filled up with dry leaves or cuttings of *kadbi* with a thick layer of fine sand on the surface. Water was supplied by capillary action from below. *Bajri* and *til*, being tiny seeds, were tested in small porous petri dishes which were placed in a seed germinating incubator.

AVERAGE GERMINATION PERCENTAGE EACH YEAR (AVERAGE OF THE FOUR ANNUAL TESTS).

Common Name.	Botanical Name.	GERMINATION PERCENTAGE.				
		1922.	1923.	1924.	1925.	1926.
Bajri	Pennisetum typhoideum ..	94.5	93.6	89.1	87.0	61.2
Jowar	Andropogon sorghum ..	89.7	90.7	90.8	84.5	79.1
Wheat ..	Triticum sativum ..	97.6	98.2	97.3	99.1	98.1
Maize	Zea Mays	96.0	97.3	96.2	89.6	86.7
Tur	Cajanus indicus	93.5	89.2	91.1	88.1	87.1
Mug	Phaseolus mungo ..	77.2	93.6	97.1	94.5	96.7
Matki	Phaseolus aconitifolius ..	90.2	93.8	93.7	91.6	93.3
Udid	Phaseolus Mungo Var. radiatus	72.2	98.1	97.3	97.7	98.3
Gram ..	Cicer arietinum	96.6	99.8	98.0	93.2	97.5
Hulga Kulti ..	Dolichos biflorus ..	99.0	98.5	98.2	98.1	97.6
Kabuli Gram ..	Cicer arietinum	97.0	99.0	98.7	96.7	97.2
Cotton Seed ..	Gossypium neglectum ..	58.6	67.3	58.0	55.8	53.3
Groundnut (Small Japan)	Arachis hypogea	92.6	74.5	60.2	28.5	23.8
Safflower ..	Carthamus tinctorius ..	97.3	98.5	96.6	96.6	94.7
Til	Sesamum indicum ..	85.6	85.8	85.6	79.2	80.5
Linseed ..	Linum usitatissimum ..	98.0	97.3	93.7	94.1	93.0

It will be seen from the foregoing table that excepting groundnut and *bajri* all the crops that have been tested have maintained a high percentage of germination throughout five years without appreciable decrease. Groundnut, however, rapidly lost its viability, especially after the third year. *Bajri* seed retained its high germination for four years but fell off in the fifth. The pulses are specially noticeable for their continued high viability. The pulses, *mug* and *udid*, gave a germination percentage of 50.5 and 21 respectively, when tested in January 1922 immediately after harvesting, the remaining seeds being impermeable "hard" seeds which gradually became permeable in the course of nine months to a year and then gave almost 100 per cent germination.

The following table and Chart II* illustrate the increase in germination and fall in the hard seed percentage (seed which subsequently became permeable).

GRADUAL DECREASE IN "HARD" SEED PERCENTAGE.

1922.

MUG.			UDID.		
Month of Testing.	Germination.	Hard seed. Per cent.	Month of Testing.	Germination.	Hard seed. Per cent.
January ..	50.5	45	January ..	21	75.5
March ..	81.5	17	March ..	72	25
June ..	84.5	9	June ..	99	0
October ..	92.5	4.5	October ..	97	0

The presence of hard seeds and their behaviour in storage has already been discussed by Prof. G. B. Patwardhan, Assistant Professor of Botany, College of Agriculture. It was shown that *muj* and *udid* which just after harvest show the presence of a large number of hard seeds or seeds impermeable when tested for germination after about a year, germinate readily. The usual procedure in seed testing is to consider half the number of such hard seeds as germinable on the assumption that those seeds may germinate at some future unknown date when sown in the field. As a matter of fact in this respect nothing reliable was known till the present work was done. The presence of such hard seeds was found to be so enormous that Mr. G. D. Mehta once in charge of this seed-testing section, recommended scarifying such seed so as to obtain uniform germination. The present work shows that scarification is not necessary. Given time, the hard seed will germinate.

The seeds when stored for this experiment appeared to be free from living weevils, yet one *matki* sample which was sealed by over-sight without a naphthaline ball was so damaged by weevils that within a year the contents became a heap of unrecognizable rubbish, while all the other *matki* samples in which the naphthaline balls had been placed were free from weevils. This clearly proves that the naphthaline effectively prevents hatching or growth of weevils in seed. The only objection to the use of naphthaline is that it renders the seed useless for human food. This objection, however, does not affect seed stored for sowing.

*The charts and graphs referred to are omitted in this Journal.—*Ed.*

The figures given justify the following statements :—

(1) With the exception of groundnut and to a less extent *bajri*, the crop seeds tested have lost little germinating power over five years.

(2) The so-called "hard" seeds of the pulses tested lose their hardiness within a year of harvesting and storage.

The experiments are being continued.

—*Agricultural Journal of India*, Vol. XXIII, Part IV.

Rice in Italy.

By D. Ananda Rao, B.Sc. (Edin.),

Deputy Director of Agriculture, Madras.

(The following note is abridged from a very i teresting and lengthy article on the subject which the author has written to the October number of the *Modern Review*, Calcutta, and which embodies the results of his personal enquiries in Italy during a holiday tour in Europe in 1927.)

India ranks highest in the area of rice it grows. In 1920-24 the average annual area was 80,683,000 acres. In Europe, Italy and Spain raise rice in large areas. Of these two, Italy grows nearly 300,000 acres.

The average annual outturn in India for 1920-24 was 47,365,017 tons whereas in Italy it was 491,968 tons. In other words while the yield per acre in India is reckoned at 1,310 lbs., that of Italy is 3,670 lbs. This is astonishingly high.

In Italy, Piedmont, the region in which Vercelli is situated, is the most productive of all ; other regions are Lombardy, Emilia, Venito, Toscana and Sicilia. The region visited is situated in the valley of the Po and is fed by it and its tributaries. The most productive centres are Vercelli, Mortora, Navasa, Pavia, Millana and Cremano. The area under rice is gradually spreading to the east as far as the sea.

Rice cultivation has seen many vicissitudes. While the area during the last fifty years has decreased by 50%, the average yield has doubled itself.

5 Year periods.		Hectares.	Quintals.
1870–74	..	232,670	4,810,900
1879–83	..	201,830	3,584,900
1890–94	..	182,450	3,046,400
1901–05	..	175,365	4,434,500
1910–14	..	144,998	4,878,700
1915–19	..	138,618	5,218,300
1920–24	..	121,408	4,698,800

(*N.B.*—One Hectare=2.4 acres ; one quintal=1.97 cwt.

Such progress must be attributed to the methods of culture rather than to the inherent richness of the soil. The Po flows through granitic rocks and does not bring with it any high fertilizing materials.

The method of sowing by hand is the common practice adopted. Only 10 per cent of the area is drilled with machines while another 10 per cent is transplanted. This last method came into vogue in 1912.

For weeding, manual labour is more largely employed than in India; very large expenditure is incurred on weeding. Women walk into the fields and weed exactly as women in India do.

Transplantation is done chiefly by manual labour. High cost of labour prevents the practice spreading rapidly; attempts are made to substitute machines. It is said that transplanting machines in use which are simple and ingeniously constructed cover 1 hectare in $1\frac{1}{2}$ hours. Harvest is done with the sickle similar to the one in use in Madras but with slight modifications.

Small bunds are absent and the whole area looks like one vast field. One would see even 20 to 30 acres without being interrupted by bunds.

Great trouble is taken to level the lands and a good deal of terracing is done. Final levelling is done by means of levelling boards as in India; only, horses are substituted for oxen. Water is allowed to flow gently to the fields. Flooding as is done in India is absent. From the main irrigation channels small distributaries are taken off about 6 yards apart through which water is let to the rice plots. Thus there is no waste of water in its distribution.

The required quantity is measured and distribution is left entirely in the hands of the cultivators themselves. There are numerous associations of cultivators to distribute water to their members, the first of the kind, the one called West Sosia Association, having been formed in 1853.

The several rice zones are divided into districts or provinces and each sends its requirements of water to the central authority which is the association of the cultivators. These associations pay to Government a certain sum for the use of water from April to September. Individual cultivators in their turn pay a certain sum to the association. Besides the canals owned by Government, there are others which are the property of cultivators.

In regard to the irrigation of rice, the fields are dried on two occasions during the growth of the crop. 25 days after sowing the field is drained for 4 or 5 days. The beneficial effects of soil aeration and root penetration at this stage are obvious. After this, water continues to flow till after the last weeding when it is withheld and the vegetative growth

is arrested. Before water is let in, artificial manures are applied after which irrigation is constant until a few days before harvest. During the last few months water is maintained constantly in order to keep the temperature of the soil uniform.

Certain permanent meadows called "Marcita" are kept up even during winter by constant irrigation. This constant flow of water keeps the soil under uniform temperature. Thus while all cultivation is ordinarily at a standstill, under irrigation it is possible to maintain a steady supply of fodder for the cattle.

Rice after rice or as it is called "risaia stabili" used to be the common method. This practice has given place now to systematic rotation of crops. There is no hard and fast rule as to the crops introduced in any particular rotation though rotation is adopted almost universally.

Around Vercelli it is usual to take one crop of a cereal like wheat or oats followed by one or two years of pasture after which rice is raised for 3 or 4 years. In regions where clay soils predominate and where drainage facilities are lacking as in Bologna and Montona, there is only one year of rice in rotation.

Before rice is cut are sown rape, clover and other pulses which, when grown, are grazed by cattle in spring. The second growth is turned into the soil as green manure.

In Vercelli, rice occupies 55 per cent of the total area, other cereals 15 per cent and pasture 30 per cent while in other regions only 20 per cent is under rice, 35 per cent under other cereals, 30 per cent under pasture and 15 per cent under industrial crops like hemp.

Owing to pasture following rice in the rotation the land becomes foul necessitating two and sometimes even three weedings. The first weeding is done in May; the second, in June and the third, in July. Cost under this head in the first year runs up to 1,500 lire per hectare which is about 25 per cent of the total cost of production and in later years, less.

Farmyard manure is the basal manure, up to 200 quintals being used per hectare. Superphosphate, ammonium sulphate, calcium cyanamide and sulphate of potash are also used, the total cost under these running up to 800 lire per hectare. These artificials are applied twice, first time in conjunction with the farmyard manure and the second time alone when the crop is three months old. Growing crops exhibit an excellent uniformity. Crops are free from mixtures and bear heavy earheads. These are the progeny of selected seed; the one seen by the writer was the one selected for early maturity with very little straw but abundance of grain. Of the several varieties tested Japanese varieties seem to have suited

Italian conditions best and selections from them occupy about 15 per cent of the crop under these.

For ploughing tractors are largely employed; electricity plays an important part in thrashing. Harvested crop is brought to the farm in horse-drawn carts and hauled up to threshing machines by electricity. By the time rice harvest is finished, winter sets in and drying of seed becomes difficult. Early maturing varieties are got in, in September when there is plenty of sunshine and with late varieties artificial drying by means of desiccators heated by steam becomes necessary, about 450 quintals being treated in this way in 24 hours.

The Italian cultivator does not sell rice in the market as paddy but hulls it by machinery before it is sold. The by-products are fed to live-stock and rice is sent to the market for sale or export. Farmers in this region are in affluent circumstances. They compare favourably with their brother farmers in Britain although the latter country is still the richest in Europe. About 300 hectares may be considered an average holding of the well-to-do people. They are all well educated. Electricity is utilized also in their homes. Almost all own motor cars, several have radio machines. Some proprietors stay throughout the cultivation season on their farms and go to their city residences in winter when work is slack. Living is less expensive in this country than in most parts of Europe. Large proprietors have tenants to whom are leased out farms of various sizes. These are by no means poor and three hectares of land are considered enough to keep small peasants in comfort.

Migrations of labouring classes from poorer localities like Montona and Bologna to richer regions like Vercelli take place during agricultural seasons. People from dry lands go to wet land districts during transplanting and harvest season as in India. The peasantry are comfortably housed; some houses are two-storied, fitted with electrical lighting and all modern sanitary appliances. A farmer whom the writer visited owns 300 hectares of land and 55 families are working under him. They have a school for the children, a reading room and a library for the use of the elders. They appeared happy and contented. Wages are paid in cash and kind but payment in kind is preferred as the value of lire is constantly changing while the payment in kind is more satisfactory and as the quantity of perquisites swells their income. Besides having houses provided for them they receive on an average about 9,000 lire per annum which includes 2 quintals of rice, 2 quintals of wheat and 8 quintals of maize. In addition they get ½ litre of milk per person per day. In actual money they receive from 3 to 4 thousand lire. They are permitted to keep pigs. Goats often take the place of cows in many

localities, a practice also prevailing in France. Fish culture is an interesting and paying subsidiary industry grown out of rice cultivation.

The standard of living of the labourer in rich tracts is high. Casual labourers work about 8 hours and get a 36 lire per man and 28 lire per woman per day. (At the time of the visit 130 lire were equivalent to one pound sterling.)

Dairy farms, pure and simple as found in Britain, are rare except near the Alps where natural meadows exist in abundance. Mixed farms are the rule. Milking cows are of the Swiss type and an average yield is 8 litres per day. Cattle insurance is very expensive and therefore horses alone are insured.

Such condition cannot be considered to be prevailing all throughout Italy. Wet land cultivators in the East are not so well off as those in the region of Piedmont or Lombardy. But on the whole wet land cultivation has brought prosperity to the people and has been characterized by the three features—extreme economy in the distribution of water for rice crop the judicious rotations followed which are suited to local conditions and which include pasture crops and the systematic and liberal manuring given which is rendered possible by the enlightened character of the peasants and the affluent circumstances in which they are placed.

With the experience gained in Italy the author recommends that for India (1) experiments should be conducted with a view to determine how far under canals and tanks water can be economized without detriment to present yields, (2) investigations should be undertaken to find out what kinds of grasses or fodders could be grown sufficiently quickly and in sufficient quantity to make it worth while for the cultivators to adopt and intersperse in the rotation, and (3) in order to spread the result of researches, education should be imparted to adults more widely than present.—*The Journal of the Madras Agricultural Students' Union*, Vol. XV, No. 12.

Agriculture in India.

(*Continued from page* 56, *No.* 1, *of this Journal.*)

The Imperial Council of Agricultural Research would consist of three whole-time officers and 36 others. Of the three, the Chairman should be of wide administrative experience and if possible, with Indian experience also and the two others would deal with agricultural and veterinary research respectively. The 36 ordinary members would represent various interests in the country: 8 would be nominated by the Government of India, 18 would represent the provinces, 3 the universities, 1 each the

Central Cotton Committee and the planting community, and the remaining 5 would be elected by the Council itself. The whole-time officers would be engaged for five years, and the rest nominated for three periods subject to extension if desired. The post of Agricultural Adviser to the Government of India would naturally lapse under this scheme, and his advisory duties would be carried on by the Chairman of the Council.

Special attention is directed to the Central Research Institute at Pusa. This, it is recommended, should be strengthened so as to become also a teaching centre for higher training in agriculture, as it is entirely desirable that India should be self-contained in this respect as soon as possible.

The allied subject of the agricultural services is dealt with in a long Chapter (XIX) at the end of the report. While we consider it of even greater importance than that of the organization of research, space forbids us from going into details. The general intention in the recommendations is to improve the status of these services on the score of efficiency and because of the increased responsibilities imposed if the Commission's suggestions are endorsed. This applies not only to the rank and file, but in a special degree to the post of provincial director of agriculture and the principal of the agricultural college, both of them being key positions in the improvement of agriculture. It is suggested that the hands of the former might be strengthened by the addition of an officer of somewhat lower status as joint director. The Commission is not in favour of short-term appointments—which are, it is true, generally uneconomic in principle and practice. As to the general recruitment for the service it is recommended that the system of scholarships so successfully initiated by the Colonial Office should be adopted; and in the case of all superior officers, it is contended that the best men should be engaged, and that therefore recruitment should not be confined to one province, or even to India. The institute at Pusa is again referred to, and the Commission recommends that the statuses of the principal and the heads of sections should be raised in view of the increased demands made upon them.

Chapter VI is devoted to agricultural improvement, and it is stated that the various factors affecting crop production, other than irrigation, are dealt with. The areas under the seventeen chief crops in India are given for general information. Soils and manures are rather fully discussed and take up about half of the chapter, a few pages are devoted to plant breeding, and a table is printed showing the areas under improved varieties; rather more space is devoted to seed distribution: agricultural implements are then considered, and a few concluding remarks are made on plant protection. The important subjects of rotation of crops and

tillage are not included in that they have been fully discussed by the recent Sugar and Cotton Committees.

There are 81 recommendations and conclusions at the end of Chapter VI although this formidable number could have been reduced by using longer paragraphs. As examples of useful conclusions the following may be given; the suggestion that the soil survey of India should be undertaken is vetoed; no diminution in the fertility of long-continued cultivated fields is anticipated; definite advice cannot be given by the agricultural department on the use of fertilizers by cultivators; neither export tax nor prohibition of export of oil seeds, oil cakes, bone or fish manures, can be justified; and no legislation is needed for the adulteration of fertilizers.

As already indicated, we consider that the chapter will prove disappointing to those interested in agricultural problems, and hoping for new light on an extremely complicated enterprise, in which, despite occasional successes, the general results of their labour has often been very disheartening. This latter aspect is reflected in the way in which the Commission has presented this part of its report; for there is a singular absence of that enthusiasm which is so marked a feature whenever they deal with rural economy. As it is, the chapter summarizes the information placed before the Commissioners and is simple and clear, with an honest attempt to make suggestions where considered of possible advantage. In many cases there is practically nothing to be done but to go on working, and the Commission accordingly has various suggestions for the New Imperial Council of Agricultural Research. But it must be remembered that this subject is rather beyond the experience of the Commission as constituted, and could only be dealt with properly by a committee of experts in the various agricultural sciences, and in the practical aspects of Indian agriculture; such a body alone would be competent to collate the evidence and to discuss the improvement of Indian agriculture.

In the previous paragraphs special attention was directed to agriculture, the first of the two main subjects dealt with by the Royal Commission on Agriculture in India; and it is perhaps worth while emphasizing here that this term has a much wider significance in the tropics than in temperate regions. The employment of the people is much more uniform and less divided into watertight compartments, and that employment is in the vast majority of cases connected with the cultivation of the land. Modern industrial development is in its infancy, and even such as exists is largely concerned with the preparation and utilization of plant products. Irrigation, with its engineering problems, is closely connected with agriculture, and especially so in such a dry country as India. Forestry, often

only of late years separated off, has many lines of contact: either direct, as in the gathering of crops, provision for grazing, wood for implements, and leaves for manure; or indirect, in its effects on the soil, water for irrigation, and the amelioration of climate. Even fisheries overlap whether in the supply of manure or occasionally in the "rotation of crops".

Co-operation is peculiarly important in the development of agriculture; communications are necessary for transport, marketing and export, while medical work and sanitation have much to do with the ability of the labourer to perform his tasks in an exacting climate. Ultimately, the whole economics of village life and the education and general uplift of the rural population are of fundamental significance. To consider Indian agriculture only in the narrow Western sense would be a colossal blunder, and as we have indicated, there was no intention that the work of the Commission should be thus limited. To all of these subjects, largely embryonic in the tropics, the Commission has turned its attention; and zealously lays them under contribution for the betterment of the second main subject of reference, namely, rural economy.

One section included under agricultural research remains to be dealt with, and that is animal husbandry, so closely related to the raising of crops as to be inseparable from it. In the monsoon regions, cultivation of the soils and transport of its products depend on cattle, in contrast with the hand labour and head-loads of portions of Africa and the machinery of Western countries. Cattle in India are not required for meat, so that their use as draught animals is peculiarly important. The subject is dealt with by the Commission in two long chapters (VII and IX) covering 130 pages somewhat curiously separated by that on forestry, and it is discussed in great detail. As contrasted with the raising of crops, the study of cattle has more definite units and is thus simplified; the staff employed is, moreover, more numerous and has been longer at work.

The number of live-stock in British India is given as 151 millions of cattle and buffaloes, and 62.5 millions sheep and goats; while in such Native States as have records the figures are 36 millions and 25 millions respectively. Compared with these figures, the numbers of horses, mules, donkeys, and camels are insignificant—another point of contrast with other parts of the world. The main function of cattle in India is draught, although buffaloes are also valuable draught animals; milk is chiefly obtained from the latter. The Commission records its opinion that in comparison with other countries, the number of cattle is in excess of that needed for cultivation, and finds that this is due to series of factors working in a vicious circle. The cattle are in general small and weak for

their work; the smaller they become, the greater numbers are reared to get useful bullocks; this increase in numbers causes larger areas to be cultivated at the expense of grazing grounds: the actual working cattle alone receive attention as regards their food and the calves and mothers get what they can: the result is smaller and weaker calves..... The points of policy should be reduction in numbers and increase in efficiency, better cultivation of smaller areas, and more attention to cows and cows-in-calf. Feeding and breeding are, and always will be, the main lines for the improvements of the Indian cattle; here and there throughout the country are found fine types carefully treated, which might serve as examples to be followed. The possibilities in these and other directions are exhaustively explored in the report.

The ravages of disease are dealt with in Chapter IX. Rinderpest, hæmorrhagic septicæmia, and foot-and-mouth disease are the most serious; and the methods adopted in checking the first of these, which takes the greatest toll of cattle annually, are described as typical of control work. For efficient cattle work the Commission considers that one inspector should be provided for every 25,000 cattle. There should be a superior officer in each district with an appropriate number of inspectors under him, which would mean 300 district officers and 6,000 inspectors for British India. An all-India veterinary college on the lines of Pusa is not advocated. The existing research institute at Muktesar should have the assistance of an officer experienced in administrative work.

Forestry is sometimes called "the handmaiden of agriculture," and is only considered in this capacity by the Commission. It is suggested that grass cutting should be developed wherever possible in place of grazing. Fuel is one product for which forest might reasonably be held responsible, but large cultivated areas have no forest to speak of, and everywhere cowdung is preferred; and although the Commission suggest the study of possible substitutes, there seems little likelihood of any change from this continual destruction of cattle manure. A re-classification of forest areas is recommended, according to the uses for which they are designed for timber and fuel, those desirable for physical and climatic reasons, fodder and grazing, and those more suitable for cultivation. One of the most promising lines would be the handing over of certain tracts adjoining the villages for control by them under certain restrictions.

The chapter on irrigation enumerates the projects at present being developed in the different provinces. For the rest, the Irrigation Committee of 1903 is stated to have treated all aspects in such a comprehensive manner that no further inquiry was considered necessary.

Communications and marketing are appropriately considered together in Chapter XI. The opening up of the country has had the effect of introducing money crops, that is, those for sale in place of direct consumption. Evidence shows, however, that there has been a deterioration in the character of the roads during the recent years; and on this account the Government of India has instituted a Road Development Committee. But this appears to deal primarily with the arterial roads, and the Commission again urges the importance of those leading to the villages, seeing in them a ready means of stimulating village thought by bringing them into closer connection with the towns.

Although the Agricultural Department had done much to improve the quality and increase the quantity of the cultivator's products, comparatively little seems to have been done to enable the producer to get the full advantage of this. Markets are numerous in India; for example in Bihar and Orissa there are 432 principal, and 2,624 minor ones and much information has been brought together and collated by the Commission. It suggests, however, that a regular survey of markets should be taken in hand, and that an expert marketing officer should be attached to each provincial agricultural department. A further attempt should also be made to standardize the weights and measures throughout India.

Under finance, land mortgages are somewhat fully considered, and the importance of facilitating redemption within a reasonable period, say 20 years, is insisted on. The Commission resolve that "the greatest hope for the salvation of the rural masses from their crushing burden of debt lies in the growth and spread of a healthy and well-organized co-operative movement, and local Governments should, therefore, give that movement all the encouragement possible."

Co-operation is very fully discussed in Chapter XIII, and the remarkable advance made in recent times is indicated by a table showing a quadrupling of credit societies during the past 11 years—from 16,690 to 65,101, with a like rise in the number of members and a somewhat greater increase in capital "Where the co-operative movement is strongly established, there has been a general lowering of the rate of interest charged by money-lenders; the hold of the money-lender has been loosened with the result that a marked change has been brought about in the outlook of people."

The formation of non-credit society (such as for seed, implements, manures, cattle insurance) is naturally a later growth; they are a much more difficult proposition, because of the need of business capacity and expert advice. The figures given in the same table for the past 11 years show an increase from 96 to 2,133, with a much greater rise in the

number of members and a still greater rate of increase in the amount of capital involved. The Commission records its opinion that single purpose societies are to be preferred to multiple purpose societies.

In Chapter XIV, the Commission returns to "The Village," and deals comprehensively with sanitary and medical matters, and especially with the various agencies, official and non-official, for the improvement of the amenities of village life. This is an exceedingly interesting and inspiring chapter, and the members of the Commission evidently have the matter very much at heart. They take the long view and enumerate, at length, the various possible directions in which they consider that a betterment can be brought about; they recognize that progress must be slow, and can only be effected through the will of the people themselves, and that a public opinion must be created among them.

Those who know their India may perhaps feel that the view is so long that it sometimes tends to become visionary. We read that in the later days "the old men shall dream dreams and the young men shall see visions"; and it is therefore appropriate that the Commission should turn for help to the universities, who "have at once an obligation and a great opportunity to assist in the work of rural development on both its economic and educative sides." Leadership is in fact required, and must come from outside. An interesting local solution is described from one of the districts in the Punjab, where young men are carefully trained as "guides" and each is posted to a number of villages to act as propagandist for improvements of all sorts and as counsellor in all welfare matters. These young men are not experts, but know where to look for them, and can thus act as connecting links between the villages and the various departments—agricultural, medical, co-operative, and so forth.

The Indian Research Fund Association is quoted as an admirable example of combination of private and official effort. The line of research under this foundation which comes to one's mind is that on human and animal nutrition already referred to in these columns. A great extension of this class of work is hoped for by the Commission—a concerted effort to improve the nutrition contained in the diet of the cultivator is a pressing need.

Education, perhaps fittingly, occupies the next chapter, for "few problems have been more anxiously debated as to the type of education best adapted to an agricultural population....." "The idea that education in rural areas should bear a close relationship to the daily lives of the people is but a recognition of the truth that the environment in which rural workers live is different from that in towns." There is not space to analyse the mass of facts and ideas which are contained in this chapter,

and we shall content ourselves with selecting two of the Commission's conclusions.

The first is in connection with the influence of female education on rural development. Very few boys attending the primary schools in British India stay long enough to attain permanent literacy. In 1921-22 the proportion of the boys attending primary schools was 32.2 per cent of the population, and that of the girls was 7.6 per cent. On the other hand, the percentages of literacy at 20 years and above were 18.13 and 1.9 respectively; it is evident that girls especially do not stay long at school. It is argued that if a mother is literate, a very strong influence will be brought to bear on keeping her children at school until literacy is assured. The Commission, for the purpose of testing this idea, suggest that "A definite effort should be made to impart literacy to a certain number of young mothers" and the results be carefully recorded.

The second is concerned with the kind of education to be given to older boys in rural India. Two existing types of such education, for boys from 14—17 years of age, are described and contrasted. In the first the school is vocational, being in fact an agricultural college and farm in miniature, with the important proviso that if the four-year course is gone through, all charges will be met by the school; in the second, agriculture is a voluntary subject in a vernacular middle school. The first type, started in 1910 in Bombay, has slowly extended, but it has not yet been taken up to any extent elsewhere; there are six schools of this type at present. The second type was started in the Punjab in 1923; there were 66 in 1926-27, and it was hoped that there would be 121 in 1927-28; in the United Provinces 20 such schools exist, where, however, agriculture is compulsory. Farms of three acres are intended, but all are not as yet provided with these. The Commission is strongly in favour of this latter class, financially and otherwise. It does not consider that the heavy cost of free vocational schools is justifiable, and there appears to be now general fall from the people for them.

The remaining chapters deal with rural industries and labour, horticulture and plantations and agricultural statistics. There are a number of graphs interspersed and a short series of appendices.—*Nature*, Vol. 122, No. 3066.

The Moisture Requirements of Tropical Crops.

By H. Martin Leake, sc.d.

Of the requirements for plant growth under agricultural conditions only carbon dioxide, the source of starch and the sugars formed by the plant, is universally present in an abundance sufficient for unrestricted growth. Of other material requirements, soluble mineral salts and organic nitrogenous matter, the quantity present may be insufficient for vigorous growth as the wide application of manures sufficiently indicates. But there are other, and as essential, requirements if free growth is to take place; of these the following are the more important.

The plant in growing incorporates into its structure the food material formed from the carbon dioxide of the air, as well as water and the salts dissolved therein which are taken up by the roots. The process is a chemical reaction which requires energy, and that energy is derived from light. Like most chemical reaction, too, it takes place only within definite limits of temperature, the optimum temperature varying with different species of plants, and the rate of formation of food material will, other conditions being favourable, vary with the temperature until that optimum is reached. The third essential is water or, better, humidity; for air humidity is as essential a factor as actual soil moisture. The plant is dependent on soil moisture not only as a medium to provide in solution the mineral requirements, but to maintain its tissues in a turgid, or unwilted condition. It is dependent on air humidity not merely to limit the loss of water contained in the tissues, but to permit the access of carbon dioxide to those tissues in which that gas is converted into starch or sugar; for the mechanics by which the plant controls evaporation of water contained in its tissues also controls the entry of carbon dioxide. When the evaporation of water is checked, the entry of carbon dioxide is likewise checked.

The essential difference between growth in the tropics and in temperate climates lies in the difference found in the incidence of these three factors, light, temperature, and humidity, under the two conditions. The seasonal variation in the length of day is less marked in the regions bordering on the tropics, and here light is not responsible for any marked seasonal variation in rate of growth, of which it is partly the cause in more northerly climes. Nor, as a rule, do the days of low light intensity, so common in a country like England, occur in the tropics. Light may be said to be adequate within the range of the duration of the day, and it is removed from consideration as a factor limiting growth under tropical conditions.

Temperature, similarly, is adequate and rarely limits the growth of plants adapted to a tropical life. To discuss whether it ever exceeds the optimum, as it undoubtedly does in the case of a temperate plant transplanted into the tropics, would exceed the limits of the present subject, which deals with crops normally grown in the tropics. Such cases, if they occur, are sufficiently rare to be neglected here; moreover, where temperature appears to be more excessive, further enquiry will probably disclose the fact that the real factor checking growth is air humidity: for really high temperatures, 110° F. and over, are associated with arid conditions.

Light and temperature thus being ruled out, humidity remains the main natural factor controlling plant growth in the tropics, and it is this essential simplification of the problem that lends importance to the study of the relation between the crop and humidity under tropical conditions. It is under these conditions that the study can be pursued freed from those complications which a deficiency of light or temperature superimposes.

Under natural conditions humidity is dependent on local rainfall and though exceptions occur in the case of floods, as in Lower Bengal and under certain special and somewhat exceptional physiographical conditions to which reference will be made later, this may be considered the normal position. Rainfall is, however, a very variable factor, but it is a variability which takes more than one form. In the first place, there is the variability which exhibits itself as intermittence. In no country does rain fall continuously and steadily; it occurs in intermittent showers of greater or less duration and greater or less amount. In the second place, there is that variability which exists between the rainfall of different regions, and which exhibits a definite annual cycle. At one extreme no dry season is demarcated; periods of comparative droughts are only to be distinguished from periods of comparative wet. Of such a nature are the regions with dense tropical forests characteristic of the equatorial belt. From these, with infinite gradations of an ever-increasing intensity of the dry season, are to be distinguished the regions with alternations of marked dry and wet, or monsoon seasons; and, ultimately, by a contraction in the duration of the wet season, the other extreme characterized by desert conditions.

It is this seasonal variability which determines the broad outlines of the agricultural practice of any particular region. In the wetter regions are grown such crops as rubber, cacao, and crops like sugar which take twelve months or more to arrive at maturity, and require continuous moisture; in the monsoon tracts are grown seasonal crops like cotton, maize, and *simsim* (Sesamum), capable of arriving at maturity before the

dry season sets in, and crops like coffee, tea, and sisal, perennial crops that is, but crops which are capable of withstanding a period of drought. The growth of crops like sugar may be extended into the monsoon area where an artificial supply of water is available for their maintenance throughout the rainless period. In this latter case the factor controlling growth may be air humidity. The main features of irrigation and its distinctive characteristics will be considered later.

It is not this seasonal variability, however, that is the main topic of this paper. The object is rather to consider that first class of variability which is illustrated by the intermittence of the rainfall. Everyone connected with agriculture is aware of the fact that the quantity of rain is not the only, or even the most important, feature. As important as quantity is distribution. Even in countries like England, where the rainfall is fairly evenly distributed and where individual falls are rarely heavy, the importance of rainfall is obvious. In tropical countries, where the falls are commonly much heavier, the distribution becomes all-important. It is a common feature of the Indian monsoon to find that the best agricultural result is obtained from definitely subnormal fall when this is well distributed. If, as is most desirable, it is attempted to measure the dependence of the crop on the rainfall—in other words to determine the agricultural value of rain—clearly, account must be taken of distribution as well as quantity. The figures of total annual rainfall are not only of little value but may be actually misleading. At Cherapunji, in the Assam Hills, the annual rainfall averages over 400 inches, and sometimes exceeds 500 inches; yet it is a hill station with a five month dry period when practically no rain falls. This may be compared with Rio with an average rainfall of some 40 inches. Yet the latter is a perennial garden in which all forms of tropical vegetation flourish. One of the heaviest falls in twenty-four hours, some 41 inches, is recorded in the dry area of Ceylon, while the heaviest fall in the writer's experience, some 21 inches in 24 hours, at Cawnpore, equals a somewhat low but totally adequate annual fall for the agriculture of the tract had it been well distributed.

Total annual rainfall was soon seen by those attempting to calculate the agricultural value of rain to offer no guide to the agricultural potentialities of a country, and efforts to arrive at that value have tended to place an increasing importance on distribution. The first serious effort in this direction is that of Rawson, a former Governor of Barbados and President of the Royal Statistical Society. In a report published in 1874 he analysed the rainfall data of that island, and calculated its influence on the sugar crop. He carried his analysis to the monthly aggregate falls without results and reverted to the annual total. His very detailed analysis of

the data, in a report occupying some 160 pages, may be summed up very briefly ; he found that 1 inch of rain responsible for 800 hogsheads of sugar in the crop yield of the following year. That he found such a relationship with the annual fall is due to the fact that the rainfall of Barbados is very equitably distributed. It is true a relatively dry period exists, but absolute drought is non-existent, while heavy rains—rains of more than 2 inches—are rare, and only associated with cyclonic disturbances which rarely touch the islands. Rawson failed to identify a feature of Barbados to which reference will be made later on, dependent on its geological formation and minimizing the effect of such drought as does occur.

Rawson's work antedates the more recent developments in statistical methods which are the features of the end of last and the current century, and further progress awaited that development. This method, the method of correlation, has formed the subject of an article in this journal by Yule and Engledow ; it has been extensively employed to determine the dependence of crops on rainfall and in temperate climates, on temperature.

Detailed reference to this work is not possible here ; summaries are to be found in papers by Mellish (*Quarterly Journal of the Royal Meteorological, Society*, 1910) and Hooker (*Journal of the Royal Statistical Society*, 1907, and *Quarterly Journal* of *the Royal Meteorological Society*, 1921). The basis of all these determinations is the division of the period of growth into a number of equal time intervals varying from six days in some investigations to eight weeks in others. The aggregate fall for the corresponding period of successive years is taken and correlated with the yield, the process being repeated with each period into which the growth season has been divided. An outstanding example of work along these lines is that of Walter and also of Moore.

Walter applied the method to the sugar crop of Mauritius in 1910. His objective was primarily economic ; an effort to work out a basis for the insurance of the crops, more especially against the losses due to the cyclonic disturbances which visit that island so frequently. If the loss is to be gauged, some estimate must be made of the yield that would have resulted had the cyclone not struck the island. Though his results were striking they were insufficient to convince the insurance companies concerned that they offered a basis for calculating risks, and the scheme fell through.

Moore, applying the same method to the rainfall and temperature data of the cotton belt of the Southern States of America, evolved in 1917 a system of estimating from those data the yield of cotton, for which he claimed an accuracy greater than that of the official estimate.

In spite of the considerable success which attended the application of the statistical method of correlation, it soon became apparent that the system was far from perfect, the greater source of error being the undue value—undue, that is, in respect of its real effect—placed upon heavy rains. Much of the recent work, consequently, is found to consist of efforts to discount heavy rain by various systems of what is known as " weighting". Walter, for instance, recognized the desirability of such weighting, and adopted a system which took into account the number of days during which rain fell. His own example may be given as an illustration of the principles of weighting. The different value to be assigned to 5 inches of rain in a month of thirty days according as it falls on one day or is distributed over twenty days, is given by the following :--

5 inches of rain on one day has a relative value of $5 \div 30 = 0.167$.

5 inches rain on twenty days has a relative value of $(5 \div 30) \times 20 = 3.333$.

More recently Fisher has evolved a new method, and applied it to an analysis of the rainfall and wheat returns of Rothamsted. The method is intricate, involving polynominals up to the fifth degree, and is one which the writer is quite incompetent to interpret into the language of that large body of the uninitiated to higher mathematics of which he is one unit. His method, however, follows those already described in this that it takes a sixty-day time unit of which the aggregate rainfall is employed.

Characteristic of all these applications of statistical methods is the division of the crop period into greater or less intervals of time, varying from six days to eight weeks, of which the aggregate rainfall of the interval is taken to measure the effect of rainfall on the crop without any allowance for a carry-over from one period to the next. By Fisher's method alone is an allowance made. Yet it is clear that the effect of rainfall does not terminate thus abruptly at the end of a period which is, moreover, arbitrarily determined without reference to the developmental stage of the plant. This point was vividly brought home to the writer in the case of the fall of 21 inches already mentioned. This though a continuous fall, occurred on August 31, September 1, approximately 10 inches falling in each twenty-four hour recording period. In any system of division of time in which the end of the month is employed as separating the periods, an alteration of a few hours only in the incidence of the fall would have placed the whole 21 inches in an earlier, or a later, period, and materially affected numerical calculations based on the resulting figures. It would appear, therefore, that any system dependent on the use of aggregate falls for arbitrary units of time is open to the criticism that it takes no account of the fact that the effect of rain, while it only commences with the

actual fall, continues for a period, indefinite but lengthy, when compared with the time intervals commonly adopted for statistical work.

To meet this criticism the writer has recently developed a method of evaluating the effect of rain which takes into account this essential characteristic.

The name of " effective rainfall " is applied to a daily figure obtained by adding to the actual rainfall of any day nineteen-twentieths of the figure similarly obtained for the preceding day. For explanatory purposes the method may be applied to the first rain of the monsoon when a dry period sufficiently prolonged to have reduced the carry-over to an insignificant figure is followed by a rain of, say, 2 inches. Nineteen-twentieths of 2 inches is 1.90 inches, which amount is carried forward to the next day. If no rain falls on this day, 1.90 inches is the effective fall of the second day, and nineteen-twentieths of 1.90 inches or 1.81 inches is carried on to the third day. But if rain, say, 0.50 inches, falls on the second day, the effective rainfall becomes $1.90+0.50=2.40$ inches, and the amount carried forward to the third day is nineteen-twentieths of 2.40 inches or 2.28 inches. In this manner a continuous curve is obtained which represents in very graphic manner the moisture conditions of a tract.

The assumption made here is this: of the rainfall of any particular day one-twentieth is lost, or fails to become effective for plant growth, and, of the remaining nineteen-twentieth, a like fraction fails to become effective during the second day, and so on. The successive fractions represent the loss due to run-off, percolation, direct evaporation from the soil and absorption by the plant. Clearly the loss is affected by such factors as temperatures and the same amount of rain is responsible for a more enduring effect in a temperate climate like England than in the tropics, and in the cooler months of the year than in the summer. The fraction of one-twentieth is, therefore, only applicable to conditions of fairly high and uniform temperature such as occur in the tropics, and would require modification for the different conditions of temperate climates.

The effective rainfall of any particular day is, thus, a measure of the soil moisture, derived from rain, available for plant growth, and takes into account the cumulative effect of all previous rain. The average effective rainfall for any particular period of days, consequently, affords a better measure of the effect of rainfall on plant growth than the aggregate of the actual daily falls for the same period. Although the method is only a preliminary approximation, undoubtedly capable of improvement and on many points open to criticism, it has been found to be of considerable use in attacking economic problems a few of which may be indicated.

The Governments of the various Provinces of India publish for trade purposes a series of "forecasts" of the principal crops. In Northern India, the Government of the United Provinces publishes early each year a preliminary forecast of the area under wheat in which the estimates of the irrigated and unirrigated areas are recorded separately for each of the forty-eight districts. Wheat sown early in November, and the unirrigated area is largely dependent on the moisture derived from the preceding monsoon which ceases in September or early October. The actual unirrigated area of wheat of the Cawnpore district has been compared for a series of twenty-seven years, first with the total monsoon rainfall, and, secondly, with the value of the effective rainfall on October 15th. The former gives a correlation of +0.82. Practically interpreted, this means that the unirrigated area of wheat can be forecasted some two or three weeks before it is sown, and with an accuracy which is greater than that given by the official system, the results of which, further, only appear some two or three months later. A similar calculation of the unirrigated area of cotton of the Cawnpore district, a calculation which, for reasons which cannot be entered into here, is considerably more complex, gives a correlation figure of +0.77. An interesting economic point which has appeared in the course of this enquiry is that, while the irrigated cotton area is largely influenced by the relative price of wheat and cotton, the unirrigated area is not so influenced. Cotton is sown on irrigation prior to the break of the monsoon and on land which, if not put down to cotton, would probably be left fallow and sown to wheat in the following October. There is here interesting proof of the foresight of the ordinary Indian cultivator and an indication that he is quite alive to relative values. Further, the dependence of area on price is more marked in the main cotton tract of the Province in the Aligarh district for instance than is the case in the Cawnpore district, where cotton is a less important crop. When, however, the unirrigated area is considered, no such relation between the area and the price is found. The dominating factor is here the nature of the early rains. If these are favourable, the cultivator will sow cotton up to the limit of his ability, for is not a bird in the hand worth two in the bush? The later monsoon may be unfavourable for wheat, and at the worst, if the cotton crop fails, it will not be too late to plough and sow wheat or at least barley.

The preliminary results here given sufficiently indicate the value of the effective rainfall in forecasting area though much remains to be done before any wide application of the method will become possible. Investigations have, however, been attempted along similar lines in the case of yield, and the two analyses undertaken may be briefly described.

The Barbados cane crop is planted towards the end of the year and reaped in February to May ; it occupies the ground, therefore, some fifteen months. There is no real dry period comparable to that of a monsoon tract though the period June to December is definitely wetter than the period January to May. There are three seasons the rainfall of which has been found to affect the crop yield ; they are the wet seasons prior to planting, the dry season subsequent to planting, and the wet season following the harvest. The correlation of the average effective rainfalls of these periods with the yield are, respectively, +0.44, +0.42 and +0.76, all of which are significant figures and definitely higher than the corresponding figures for the total rainfall for the corresponding periods. An analysis of Rawson's figures is now being worked out, his report giving the necessary data including daily rainfall returns from 1847 to 1872 ; but the present results draw attention to a point, not recognized by Rawson, that the rainfall of the wet season prior to planting, and, therefore, two years prior to harvest, has a material affect on the yield. The explanation is probably to be found in the nature of the coral rock of which Barbados is built. By it, to a greater extent than in normal soils, the water is held as in a sponge to be returned to the surface during the succeeding dry weather when the young sets are establishing themselves. A somewhat similar phenomenon is met with in Bihar where indigo used normally to be sown in March, although there might have been no rain later than early in the October previous, and none could be expected before mid-June. Here however, the supply of water for germination and growth of the young Indigo plant is due to the upward thrust imported by the head of water in the Hills and derived from the previous monsoon.

One other analysis may be referred to because it illustrates a further development of the use of the effective rainfall, and, dealing as it does with the cotton crop of the Dhulia Farm in the Bombay Presidency, it will be of special interest to readers of this journal. The general interest, however, arises from the fact that, in this case, there is direct evidence of the evil effect of excessive, as well as deficient, moisture.

The general habit of the cotton plant is too well-known to require description here. The essential features are that a period of vegetative growth is followed by a flowering period when, if the fruits set, the food materials formed by the plant are gradually diverted from vegetative growth to the developing bolls. The cessation of vegetative growth which results automatically reduces flower production ; but, with the ripening of the first bolls, food material is released for further vegetative growth and, with it, renewed flowering. The normal flowering curve of the cotton plant is, therefore, bimodal and the crop is the sum

of the produce of two flushes though, in practice, the product of the first flush only is collected and the crop cut out before the second flush develops. The moisture requirements of the cotton plant differ materially at the different stages of its developments. Being sensitive to excessive moisture—it is a common Indian saying that a good cotton year is a half-famine year, it requires adequate, but not excessive, moisture during the first or vegetative period, and a relatively dry period during the first flowering period, for too much rain at this stage leads to excessive boll-shedding. With the cessation of the first flowering period the crop requires adequate rain to give renewed vegetative growth, and it is even able to withstand heavy rain if this is not too prolonged to damage the ripening fruit; while, with the development of the second flush, a diminution of the rainfall is necessary if the bolls are to mature.

Working from this basis, it has been found possible to draw two curves representing respectively the upper and lower limits of moisture requirement. Where the moisture, as measured by the effective rainfall, falls below the limit given by the lower curve, the plant suffers in yield as is also the case when the moisture rises above the upper limit. As long as the effective rainfall curve lies between the limits of the two curves the plant suffers no injury and, hence, by adding the positive divergencies above the upper limit and the negative divergencies below the lower limit a measure of the divergence of the season from the optimum is obtained. In the case of the Dhulia farm crop a correlation of 0.70 has been obtained.

The possibility of calculating such a dual effective rainfall curve for a crop, however, has wide implications. The above analysis refers to a plant of the "neglectum" type of cotton with a very short season. It is certain that a similar characteristic curve, and one readily distinguishable from the above, could be worked out for cotton of the American type. The dual curve appears, in fact, to have a specific and even varietal significance. Such a result, if confirmed by further work, would be important. On the available information it is already possible, by working out in the above manner the rainfall data of a tract in which cotton has not hitherto been grown, to indicate broadly the type and with considerable accuracy the best season for sowing. Further work along these lines with the object of determining the curves characteristic of different varieties should render it possible to state on *apriori* grounds the varieties best suited to any particular tract for which the daily rainfall data are available.

Agricultural development, however, is not limited to tracts with adequate rainfall. There are large and important tracts where a deficient rainfall is reinforced by irrigation. Here an entirely new set of conditions

arises. Irrigation, like rain, adds moisture to the soil, and provides adequate moisture to the roots, but it has a relatively small effect on air humidity which may now become the controlling factor of the plant growth. The phenomenon is well known to all who have practical experience of agriculture in hot and dry countries. In Northern India the cane crop is planted in February and March, and is kept alive over the succeeding hot weather by irrigation. But, whatever the amount of water supplied, growth is negligible, for the hot dry air induces closure of the stomata, which, in its turn, checks the formation of food materials. Under these conditions no interpretation of irrigation water in terms of rainfall will enable an estimate of yield to be made, for the reason that it is not the available moisture in the soil, of which the effective rainfall is a measure, but the air humidity, which now controls growth.

A most interesting example of what appears to be an illustration of this condition is to be found in the Sudan. The report on the Anglo-Egyptian Sudan for 1926–27 (published by the Empire Cotton Growing Corporation) contains the following passage :—

"One extremely interesting feature was noted, and that was the entirely different behaviour of the cotton on the Gezira Research Farm, compared with the previous year and with former experience in the Gezira.

The difference lay in the fact that the phenomenon of suppression of the lower fruiting branches were commonly produced in the tenth or eleventh leaf axil of the stem, as against the twelfth or fourteenth axil in the previous season's crop. This effect was shared by all the cotton plots in the Gezira Research Farm, and by all varieties (in different degrees) in those plots. The change would not have been considered very remarkable, if it had not been noted that the plants at the adjoining Barakat Seed Farm did not show it. The behaviour there was that of the normal Gezira type noted in last year's report, fruiting branches being produced in the thirteenth to fifteenth axils, or even higher. An examination of the cotton in the neighbouring areas showed that it agreed with the normal Barakat type.

The improvement in appearance of the crop at the Research Farm was very striking, the usual "legginess" being practically absent. This improvement was accompanied by a very much improved yield, and by an entirely different manner of "arrival" of the crop as compared with Barakat."

There is here a very marked change in habit of the plant from abnormal to normal, a change which is apparently due to differences of

environment so slight as not to be immediately apparent. On this aspect the report continues :

"The reasons for this difference in behaviour are being investigated and it is hoped to publish the results at a later date, but it would seem probable that they are connected with the presumably higher moisture content of the soil at Wad Medani brought by an extra watering given in the earlier stages and conserved by more frequent surface tillage, or possibly by a lower soil temperature or air temperature induced by these waterings."

The main present interest of the observations here recorded lies in the fact that the conditions under which the plant is growing at the time when the first fruiting branches are forming appear to be critical; a change so small as to be far from obvious, being sufficient to produce a marked change of habit in the direction of increased health. The plant is evidently exposed to a water strain; but water strain may be induced either at the point of entry, the root hairs, or at the point of exit, the stomata.

In the former it is not necessarily the absolute amount of water contained in the soil which regulates the supply to the plant; it may be the rate at which moisture moves through the soil to replace water taken up by the plant through the root hairs. A strain so induced would, in consequence, assert itself relatively early in heavy soils, such as are characteristic of the Gezira. In the latter case the strain is induced by external factors, air humidity or temperature, the effect of the former being emphasized by air motion—that is by wind. Within limits therefore, the water strain may be controlled from either side in a manner similar to that by which the draught to a furnace may be controlled by dampers set either in front of the fire box or in the flue. Temperature and air humidity are both variable factors, showing a marked diurnal fluctuation, and it is conceivable that the plant is subjected to a limitation imposed alternately at the roots and at the shoots. It is possible, therefore, that a general increase of air humidity, or a fall in temperature, the effect of which would be to round off the peaks of the evaporation curve, would be effective even if that effect were the indirect one of reducing the plant drain on the soil moisture. And where the adjustment is so fine as the observations indicate, a very light change might be sufficient to produce a marked change of habit.

In following this line of thought it is hardly possible to avoid associating the phenomena with another characteristic of the Gezira tract; there is here an area of 300,000 acres of cultivated land, of which some 100,000 acres are under crop, placed in the midst of an extended desert in which the only free water surface is the narrow strip of the Blue Nile.

This area, moreover, has only recently been attained. Is it not conceivable that, with this increased area, a general rise of air humidity has resulted which, though too small to be readily detected among the large daily fluctuations, is adequate to produce the observed fact? Such an affect would not be uniformly apparent, and would be likely to occur locally where conditions favour the formation of pockets of relatively still fair.

Certain observations of Williams (Bull. 32, Technical and Scientific Service, *Ministry of Agriculture*, Egypt, 1923) on the conditions under which cotton is grown in different countries would seem to point in the same direction. In this note he draws attention to the similarity of the temperature at the commencement of the picking in all countries except Mesopotamia. But the phenomena in the Sudan concern the early stages of growth.

If his diagrams be studied, it will be noticed that three countries exhibit an excessive temperature at this period: the Sudan, with an average mean temperature of 29 degrees C. to 31 degrees C.; Madras, with an average mean temperature of 28 degrees C. to 29 degrees C.; and Nigeria, with an average mean temperature of 27 degrees C. to 28 degrees C. The remaining countries have mean temperatures ranging from 12 degrees C. to 21 degrees C. Of these three countries Sudan only has a marked low air humidity, and it is an obvious temptation to look out to those two abnormal conditions, high temperature and low humidity, for an explanation of the abnormal development of the plant.

The problem in the Sudan is here referred to because it illustrates better than any other known to the writer, the intricacy of all problems concerning the water balance of the plants in the fields. What the true explanation may be, and whether there be any basis for the speculations here outlined, for on the available information they cannot be other than speculations, will only be determined by the work now in hand in the Sudan.

It would appear then that in the tropics, while humidity is the major factor controlling the growth of the plant, that control is exercised in two entirely distinct ways; through the soil as soil moisture, and through the air as air humidity. The former phenomenon is regularly exhibited, and, since the fluctuations in the soil moisture are relatively slow, considerable progress has been made in the determinations of their effect on the growth of the crop. Fluctuations in the air humidity are much more erratic, and rapid in their incidence. Not only is there frequently a large daily fluctuation, but those changes are intimately bound up with other conditions such as insolation and temperature, and the

effect of air humidity as distinct from these others is not readily determined. The plant itself, too, possesses a greater capacity to adjust itself to these rapid fluctuations. The writer well remembers the first introduction of the Natal-Java indigo plant into Bihar early in the century. Seed was obtained from both countries, and though specially the same plant, there was a marked varietal difference between the plants according to their source. Seed is harvested by cutting the plant and laying it out to dry, and, on drying, the pod is explosive and capable of throwing the seeds some yards. In one case the plants of the two varieties had been cut and laid out to dry in close proximity, with the result that the seed became inextricably mixed and the subsequent crop was likewise mixed. It was possible, however, merely by standing beside a field during the hot part of the day to pick out the two varieties with certainty; for one (memory does not at this distance of time carry with any certainty which one) was distinctly more delicate, and in it the leaflets had closed on to each other and the whole leaves were folded round the stem, while the hardier variety did not require to make use of this adaptation against excessive insolation and air humidity. The water balance of crops under arid conditions and irrigation thus offers problems of a complexity greater than is the case in a rainy tract.—*The Empire Cotton Growing Review*, Vol. V, No. 3.

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